

Fluorine and Chlorine Contents in the Products of the 1783 (Temmei) Eruption of Asama Volcano

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Fluorine and chlorine have been determined for all the products of the 1783 activity of Asama volcano. The activity displayed various features that are characteristic of andesitic eruptions, i.e., pumice falls, two types of pyroclastic flow (the Agatsuma and Kambara pyroclastic flows), and the Oni-oshidashi lava flow. Their F-Cl variation patterns differ from each other according to the nature of the eruption. The pumice samples have very uniform and the highest Cl contents of all the eruptive products, despite their vesiculated texture. This is explained by the enrichment of volatiles in the uppermost part of the magma column at the beginning of the eruption. The Agatsuma pyroclastic deposit samples show the lowest Cl and F contents and the largest variations. An intense release of gas from the pyroclastic flow after the effusion is thought to have caused this. The F and Cl contents of essential blocks in the Kambara pyroclastic flow deposits, together with the field observations, suggest that the release of gas from the essential material contributed little to the fluidization of this pyroclastic flow. In conclusion, the transition from one mode of eruption to another observed in the 1783 activity of Asama must be intimately related to the variation of the volatile contents of the magma at the time of the effusion.

Key words: fluorine, chlorine, volatile contents, pyroclastic flow, Asama Volcano

1. Introduction

Fluorine and chlorine are the next, most abundant volatile components after water in volcanic rocks and are important constituents of high temperature volcanic gases. Yoshida (1963; 1975; 1990) carried out model experiments to simulate the behavior of F and Cl during the release of gas from magmas. He heated powdered igneous rocks in nitrogen flows (atmospheric pressure) at temperatures from 400 to 1200°C (Yoshida, 1963). Chlorine was easier to release from rocks than fluorine; hence the $(F/Cl)_{\text{gas}}$ ratio was smaller than the $(F/Cl)_{\text{rock}}$ ratio. Comparing the results with natural data, he concluded that F is less volatile than Cl in the separation process of the gas phase from the silicate melts. Then, he conducted further experiments for the reaction of volcanic gas with volcanic rocks (Yoshida, 1975). The gases released from powdered volcanic rocks on heating at 1000°C were passed through a column packed with rock grains (column temperature: 850–150°C). Fluorine was easier to be fixed by reaction with silicates than chlorine. The F and Cl contents and the F/Cl ratio in volcanic products will therefore be useful indicators of

the behavior of volatiles in volcanic processes.

Release of volatiles from magma is thought to play an important role in the formation and transport of pyroclastic flows (e.g., Aramaki, 1957; Aramaki and Yamasaki, 1963). Hence it is expected that a study of volatile components in pyroclastic deposits might provide useful information. There exist, however, very few systematic studies of the halogen contents of pyroclastic deposits. All we have is a report on the chlorine content of the Aso pyroclastic deposits by Iwasaki and Ono (1967).

The Temmei-activity of Asama volcano in 1783 was the last large-scale eruption from the Maekake-yama crater and manifested various characteristic features of andesitic eruptions. Many old documents concerning this activity have been preserved and their essential information can be found in scientific literatures (e.g., Aramaki, 1956; 1963; 1968).

The eruption started on May 9, 1783 and in the earlier stage produced pumice and ash. Especially after July 25, the pumice eruptions occurred frequently and violently. Total volume of the pumice and ash

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deposit amounts to 0.17 km^3 . On August 4, an intermediate type pyroclastic flow (Aramaki and Yamasaki, 1963), the Agatsuma pyroclastic flow, rushed down the northern slope and spread over an area of about 20 km^2 (volume: 0.1 km^3). A pyroclastic flow of another type, the Kambara pyroclastic flow, occurred the next day, August 5, with very strong detonations and caused very serious disasters. Its deposit consists of large essential blocks in the upper part of the flow, while the lower part consists mainly of secondary materials. Total volume of the deposit is estimated as 0.01 km^3 . The activity ended with the effusion of the Oni-oshidashi lava flow (volume: 0.17 km^3) poured out immediately after the Kambara pyroclastic flow (Aramaki, 1956; 1963; 1968).

All the products of the 1783 eruption are andesites with practically uniform chemical compositions. The major and minor components vary a little despite the very different nature of the successive effusions (Fukuoka and Aramaki, 1986; Sato *et al.*, 1989). For this reason, we presumed that the transition from one type activity to another during the 1783 activity was caused by difference in mode of gas-release from the magma at the time of the eruption. We determined the F and Cl contents in all kinds of volcanic products of the 1783 activity and examined their eruptive mechanism from this viewpoint.

2. Samples

The analyzed samples are the essential products of the 1783 activity except the K-11 and K-12 samples (Table 1). Sampling locations are shown in Fig. 1. Pumice samples were obtained from the exposure near the Asama Volcano Observatory of the Earthquake Research Institute, University of Tokyo. They are numbered from the bottom to the top of the deposit. Samples A-1 to A-4 of the Agatsuma pyroclastic flow were those of different appearances collected at the same outcrop. That is, A-1 and A-2 were taken from the compact and porous part of a block resembling bread-crust bomb, and A-3 and A-4 were from the loose matrix of the deposit. The other Agatsuma samples were taken from different parts of the deposit. Samples of the Kambara pyroclastic flow K-1 to K-3 were taken from the same block, K-1 from the main part, K-2 from the chilled margin, and K-3 from the porous part. The pairs K-6–K-7 and K-9–K-10 were also taken from corresponding parts of other blocks; K-6 and K-10 were from the main parts, K-7 from the glassy part and K-9 from the outside. Sample K-11 is the muddy matrix of the secondary material in the lower part of the flow and K-12 is a mud-layer (2 to 3 mm thick) that covered an essential block at the same locality.

3. Analytical method

Fluorine was determined by the method of Tsuchiya *et al.* (1985). A powdered sample is fused with Na_2O_2 in a nickel crucible. The cake is dissolved in water and fluoride in the solution is distilled as trimethylfluorosilane. The fluoride concentration in the distillate is determined with an ion selective electrode.

Total chlorine was determined by the method of Iwasaki *et al.* (1955) as improved by Ozawa (Yoshida *et al.*, 1994). A powdered sample is fused with Na_2CO_3 in a platinum crucible. The cake is dissolved in water and the resulting suspension is centrifuged. Chloride in the solution is determined by mercuric thiocyanate-spectrophotometry (Tomonari, 1962). Water-soluble chlorine is extracted by immersing the rock powder overnight in water and measuring again by mercuric thiocyanate-spectrophotometry.

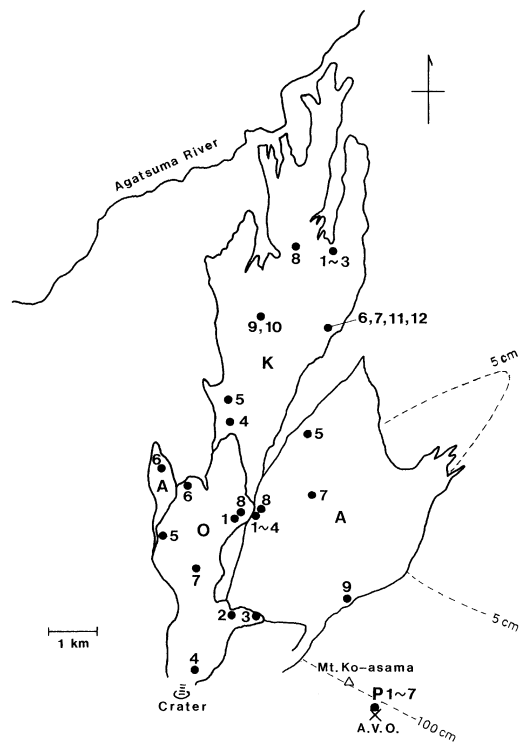


Fig. 1. Sampling locations of the rocks of the 1783 eruption of Asama volcano: A=Agatsuma pyroclastic flow; K=Kambara pyroclastic flow; O=Oni-oshidashi lava flow; P=Pumice fall deposit; A. V. O.: The Asama Volcano Observatory. --- Isopach curves of the pumice fall deposit. (5 cm and 100 cm)

Asama-yama is situated at $138^{\circ}31'E$ and $36^{\circ}24'N$.

4. Results

Analytical results with various statistical parameters are shown in Table 1a to 1d according to the type of eruption. The errors in the determination of both F and Cl are $\pm 10 \mu\text{g/g}$. Water-soluble Cl in Japanese volcanic rocks are usually less than $50 \mu\text{g/g}$ and can often be attributed to secondary contamination (Iwasaki *et al.*, 1957; Yoshida *et al.*, 1971). In the present case, most water-soluble Cl contents are less than $50 \mu\text{g/g}$ and the discussion is based mainly on the water-insoluble Cl which is calculated as the difference between the total Cl and the water-soluble Cl.

Halogen contents of volcanic rocks have approximately lognormal distributions (Iwasaki *et al.*, 1957; Iwasaki *et al.*, 1968; Yoshida *et al.*, 1971), and it is more appropriate to use logarithmic values for applying statistical analysis to the data for F and Cl contents. We take logarithms of their contents for most discussion. The arithmetic mean values are also shown, because it is more commonly used as a statistical expression.

Arithmetic means(m) and standard deviations(s) of log F and log Cl values ($\mu\text{g/g}$) for Japanese volcanic rocks ($n=128$) are $m(\log F)=2.48$, $s(\log F)=0.33$ and $m(\log Cl)=2.18$, $s(\log Cl)=0.50$ (Yoshida, unpublished data). The $m(\log X)$ values for the Oni-oshidashi lava samples (Table 1d) are included within the range: $m(\log X) \pm s(\log X)$ of Japanese rocks, so we can say that the 1783 Asama rocks have halogen contents typical of Japanese volcanic rocks.

5. Discussion

5-1 Statistical examination of the difference of the F and Cl contents with the type of eruption

The F and Cl contents of the pumices, the Agatsuma and Kambara pyroclastic flow deposits, and the Oni-oshidashi lava samples seem to be different from one another (Table 1; Fig. 2).

The F content of the A-5 sample is markedly different not only from the other Agatsuma samples but also from all the other samples. Q-test for outliers (Dixon, 1953) shows that the A-5 sample does not belong to the same lognormal distribution as either that of the other Agatsuma samples or that of all other samples at the 1% significance level. We therefore disregard this sample in most of the following discussion.

Whether the mean logarithmic values $m(\log X)$ of the groups differ significantly from one another has been examined by t-test (Table 2). Also differences of the variances $\{s(\log X)\}^2$ among the groups are examined by F-test (Table 3). The results support the deduction from Tables 1a–1d and Fig. 2 that the F and Cl contents of the volcanic products strongly depend upon the type of eruption.

The Cl contents of the pumice samples are very

uniform and are higher than the others at the 1% significance level. On the other hand, their F contents are almost the same as those of the Kambara pyroclastic deposit and the Oni-oshidashi lava flow. The Agatsuma pyroclastic samples are in striking contrast to the pumice samples, even though they erupted next to the pumice eruptions. They show the lowest F and Cl contents, the highest F/Cl ratio and the largest variations in these values. The essential blocks of the Kambara pyroclastic flow have the highest Cl contents after those of the pumice samples. The variance of their Cl contents is only slightly larger than those of the pumice and the Oni-oshidashi samples, and distinctly smaller than those of the Agatsuma samples. The Oni-oshidashi lava samples have the second lowest Cl contents, while the variances are comparable to those of the pumice samples. The statistical examinations above-mentioned indicate that F and Cl were differentiated to different degrees during the process of magma effusion.

5-2 Difference of the Cl contents between the pumice and the lava

One might attempt to explain the difference of the Cl contents between the pumice and the Oni-oshidashi samples as reflecting a greater amount of Cl released from the lava flow after the effusion than from the pumice. This explanation is based on the view that pumice is thrown up in the air and quenched as glass, whereas minute crystals grow in lava flow during cooling and Cl is expelled from melts as minerals crystallized out then escape to the air. Iwasaki and Ono (1967) found that the Cl contents in the Aso-III pyroclastic flow deposits depend on crystallinity of the matrix of rocks. They explained the results by the mechanism above-mentioned and thought that Cl was emitted through secondary fumaroles. Furthermore, emissions of great amounts of halogen-rich gases were observed for about 15 years in the Valley of Ten Thousand Smokes which was formed from the pyroclastic deposits of the 1912 activity of Katmai volcano in Alaska (Hildreth, 1983; Zies, 1929). These deposits have very large volume (Aso-III: $\sim 80 \text{ km}^3$; Katmai: $\sim 20 \text{ km}^3$) and their inner parts could maintain high temperature for a long time. Thus, release of Cl by the above mechanism is very plausible.

Gas emissions from lava flows have also been observed, and those high temperature gases have quite high Cl contents (e.g., Iwasaki, 1970). However, the amounts of the gases are small, and the gas-emission has only a short duration, as observed in the 1983-Miyakejima and 1986-Izu-Oshima eruptions (Hirabayashi *et al.*, 1984; Hirabayashi *et al.*, 1988). In accordance with these results, the Cl contents of the lava samples of these eruptions have a rather small variance (Hirabayashi *et al.*, 1984; Yoshida *et al.*, 1994). The volume of the Oni-oshidashi lava flow is estimated to be

Table 1a. F and Cl contents of the pumice fall samples of the 1783 eruption of Asama volcano.

Sample	F ($\mu\text{g/g}$)	Cl _{total} ($\mu\text{g/g}$)	Cl _{H₂O-sol.} ($\mu\text{g/g}$)	F/Cl _{insol.} (atom)
P-1	270	490	< 10	1.03
P-2	310	540	< 10	1.07
P-3	310	550	10	1.07
P-4	300	530	10	1.08
P-5	300	530	10	1.08
P-6	290	530	10	1.04
P-7	310	540	< 10	1.06
a.m. ^a	298.6	524.3 ^b		1.062
s.d. ^c	14.64	18.13 ^b		0.0195
m (log X) ^d	2.475	2.719 ^b		0.0262
s (log X) ^e	0.0219	0.0152 ^b		0.00803
g.m. ^f	298.5	523.6 ^b		1.062

These samples are provided by Prof. S. Aramaki.

^a Arithmetic means.

^b Calculated for water-insoluble Cl.

^c Standard deviations

^d Arithmetic means for log X.

^e Standard deviations for log X.

^f Geometric means.

Table 1b. F and Cl contents of the Agatsuma pyroclastic flow deposit samples of the 1783 eruption of Asama volcano.

Sample	F ($\mu\text{g/g}$)	Cl _{total} ($\mu\text{g/g}$)	Cl _{H₂O-sol.} ($\mu\text{g/g}$)	F/Cl _{insol.} (atom)
A-1	200	410	40	1.01
A-2	230	190	40	2.86
A-3	230	290	20	1.59
A-4	230	300	30	1.59
A-5	740	380	50	4.18
A-6	260	440	30	1.18
A-7	180	340	20	1.05
A-8	300	280	30	2.24
A-9	200	240	30	1.78
a.m. ^{a,g}	228.8	281.3 ^b		1.662
s.d. ^{c,g}	37.96	84.08 ^b		0.6354
m (log X) ^{d,g}	2.354	2.431 ^b		0.1946
s (log X) ^{e,g}	0.0701	0.1390 ^b		0.1591
g.m. ^{f,g}	225.9	269.8 ^b		1.565

Samples A-5 to A-9 are provided by Prof. S. Aramaki.

^{a-f} Same as in Table 1a.

^g The sample A-5 is omitted as an outlier.

Table 1c. F and Cl contents of the Kambara pyroclastic flow deposit samples of the 1783 eruption of Asama volcano (K-1 to 10 are taken from essential blocks).

Sample ^g	F ($\mu\text{g/g}$)	Cl _{total} ($\mu\text{g/g}$)	Cl _{H₂O-sol.} ($\mu\text{g/g}$)	F/Cl _{insol.} (atom)
K- 1	280	460	40	1.24
K- 2 ^h	270	480	20	1.10
K- 3 ⁱ	260	360	40	1.52
K- 4	290	460	30	1.26
K- 5	260	430	10	1.16
K- 6	290	430	10	1.29
K- 7 ⁱ	290	440	40	1.35
K- 8	250	390	10	1.23
K- 9 ^k	310	490	20	1.23
K-10	380	440	10	1.65
a.m. ^a	288.0	415.0 ^b		1.302
s.d. ^c	37.06	42.23 ^b		0.1664
m (log X) ^d	2.456	2.616 ^b		0.1115
s (log X) ^e	0.0518	0.0470 ^b		0.0530
g.m. ^f	285.8	413.0 ^b		1.293
K-11 ^l	340	300	10	2.17
K-12 ^m	360	320	10	2.19

^{a-f} Same as in Table 1a.

^g Samples bound by braces are taken from the same blocks.

^h Chilled margin. ⁱ Porous part. ^j Glassy part.

^k The outer part. ^l Matrix of muddy secondary materials.

^m Mud layer adhering to an essential block.

Table 1d. F and Cl contents of the Oni-oshidashi lava samples of the 1783 eruption of Asama volcano.

Sample	F ($\mu\text{g/g}$)	Cl _{total} ($\mu\text{g/g}$)	Cl _{H₂O-sol.} ($\mu\text{g/g}$)	F/Cl _{insol.} (atom)
O-1	280	350	< 10	1.49
O-2	280	380	20	1.45
O-3	280	380	20	1.45
O-4	310	410	30	1.52
O-5	310	380	10	1.56
O-6	310	400	10	1.48
O-7	280	330	10	1.63
O-8	310	400	30	1.56
a.m. ^a	295.0	362.5 ^b		1.520
s.d. ^c	16.04	21.21 ^b		0.0633
m (log X) ^d	2.469	2.559 ^b		0.1815
s (log X) ^e	0.0236	0.0261 ^b		0.01791
g.m. ^f	294.4	362.2 ^b		1.519

Samples O-2 to O-8 are provided by Prof. S. Aramaki.

^{a-f} Same as in Table 1a.

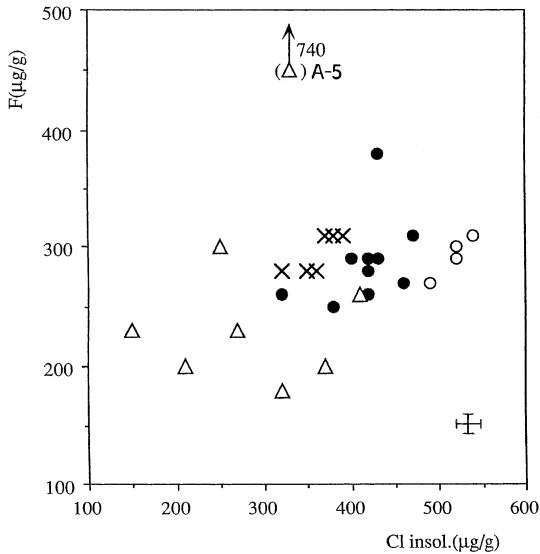


Fig. 2. F-Cl_{insol.} variation patterns for the samples of the 1783 eruption of Asama volcano: ○ = Pumice samples; △ = Agatsuma pyroclastic flow samples; ● = Kambara pyroclastic flow samples; × = Oni-oshidashi lava samples; (△) = A-5 sample which is omitted as an outlier. ± Error bars

~0.17 km³ (Aramaki, 1956). This is a little larger than those of the 1983-Miyakejima (~0.01 km³) and 1986-Oshima (~0.03 km³) lava flows, but far smaller than those of the Aso and Katmai pyroclastic flows. The rate of cooling of the Oni-oshidashi lava flow might be comparable to those of the Miyakejima and Oshima lava flows and far faster than those of the Aso and Katmai flows. Then, it can be concluded that the loss of Cl after effusion did not affect markedly the Cl content of the Oni-oshidashi lava flow. The uniformity of the Cl content in the Oni-oshidashi samples supports this view.

Pumice must certainly be quenched shortly after the effusion. But, judging from its well-vesiculated texture and the violent eruption by which pumice is thrown out, we should say that large amounts of gas were released at or just before the time of the eruption. In order to interpret the higher Cl content of the pumice samples than that of the lava, we must suppose that the pumice-generating magma had considerably higher Cl content than the lava-generating magma. Sekine *et al.* (1979) studied near-liquidus phase relations in dry and water-saturated high pressure conditions on products of andesitic eruptions including the 1783 Asama activity. They concluded that at the beginning of the eruption,

Table 2. Difference among the mean logarithmic values $m(\log X)$ of the groups examined by t-test^a.

F:	Pumice ~ Oni-oshidashi ~ Kambara ≫ Agatsuma
Cl _{insol.} :	Pumice ≫ Kambara ≫ Oni-oshidashi > Agatsuma
F/Cl _{insol.} :	Agatsuma ~ Oni-oshidashi ≫ Kambara ≫ Pumice

^a≫ means that the difference is significant at the 1% level; > means that the difference is significant at the 5% level; ~ means that the difference is not significant at the 5% level.

Table 3. Difference among the logarithmic variances $\{s(\log X)\}^2$ of the groups examined by F-test^a.

F:	Agatsuma ~ Kambara ~ Oni-oshidashi ~ Pumice Agatsuma > Oni-oshidashi
Cl _{insol.} :	Agatsuma ≫ Kambara ~ Oni-oshidashi ~ Pumice
F/Cl _{insol.} :	Agatsuma ≫ Kambara ≫ Oni-oshidashi ~ Pumice

^a≫ means that the difference is significant at the 1% level; > means that the difference is significant at the 5% level; ~ means that the difference is not significant at the 5% level.

the uppermost part of the magma column should have been saturated with water and the H₂O content was lower in the lower part of the magma column. Our results are consistent with theirs and strongly indicate a vertical gradient of the Cl content similar to that of H₂O. On the other hand, the difference in the F content between the pumice and lava samples is small and the behavior of F and Cl might be different during the vertical migration of volatiles in the magma column.

5-3 Variation in the F and Cl contents of the pyroclastic flow deposits

When we consider that the vertical change of the Cl content is gradual, the magma from which the Agatsuma pyroclastic flow was generated should have had the second highest Cl contents. However, the Cl and even the F contents of the Agatsuma samples are the lowest, and the F/Cl ratios have the highest values of all the eruption products. Furthermore, variations of the F and Cl contents, and the F/Cl ratios are considerably larger than the others (Fig. 2, Table 3). Putting all these observations together, we can deduce an intense release of Cl and F from the Agatsuma pyroclastic flow after its effusion. This is consistent with the surface flow of high-temperature, gas-releasing, fragmental material. After rather long duration of the

pumice eruption, somewhat less volatile-rich magma would come up to the vent. The magma would have vesiculated at the mouth of the vent and would overflow without being ejected vertically. In this case, the magma would maintain high temperature and volatiles would be released by vesiculation after the effusion, and the F- and Cl-poor, heterogeneous deposits could be produced.

Incidentally we can offer a plausible reason for a high-F value in the A-5 sample. The model experiments for the reaction of volcanic gas with silicate rock (Yoshida, 1975; 1990; Yoshida *et al.*, 1968) show that F is preferentially fixed on the rock grains in a water-insoluble form, while a smaller amount of Cl is fixed mainly in a water-soluble form. The A-5 sample was obtained from the surface of the flow (Aramaki, private communication). The gas of high halogen contents released from the pyroclastic flow might react with a rock at the surface where the temperature is relatively low. The fact that the A-5 sample contains a slightly higher water-soluble Cl may support this explanation.

The Kambara pyroclastic flow has a quite different appearance from the Agatsuma pyroclastic flow (Aramaki, 1956). Huge essential blocks are found in and around a channeled area which ends in a large amphitheater in the upper course of the flow where deposits from the past activity are strongly eroded. Excavation of the buried village at Kambara-mura has revealed that the deposit in the lower course consists mostly of low-temperature, dry debris from secondary sources and contains only a small proportion of essential fragments (Aramaki *et al.*, 1986). The essential blocks are thought to have had high temperature at the time they were emplaced, for their direction of remnant magnetism is parallel to the present field, and their smooth glassy skins have expansion cracks. Geological studies (Suzuki *et al.*, 1986; Aramaki *et al.*, 1986) reached the following conclusion. During the pumice eruption, the magma might be partly solidified around the fringe of the vent. The semisolid mass formed in this way might plug the vent temporarily after the effusion of the Agatsuma pyroclastic flow and be thrown out with a violent outburst of compressed gases. The huge essential blocks ejected from the crater rushed down the steep slope or were thrown up and landed directly on the present site of the amphitheater (Aramaki, 1963). The blocks deeply scoured the old deposits and transferred their kinetic energy to the excavated materials which constitute the major portion of the lower course of the flow.

The F and Cl contents and their variations in the essential blocks of the Kambara pyroclastic flow indicate that the amount of gas released from the blocks after the effusion was insignificant compared with that of the Agatsuma deposit. However, variations of the

contents within a block, coupled with the inner structures, suggest that the temperatures of the blocks were high enough to cause some migration of volatiles within it. While, the mud layer adhering to the blocks has almost the same F content as the matrix of the deposit near the block and secondary enrichment of F, such as that observed in the A-5 sample, is not seen. We estimate, therefore, that the temperature of the blocks was around 800°C at the time of deposition, because halogen can migrate to a small extent at that temperature (Yoshida, 1963). By all accounts, the release of high temperature gas from the essential materials might not play an important role in fluidization of the Kambara pyroclastic flow. This deduction is consistent with the conclusion reached in the geological study mentioned above.

6. Conclusions

Determinations of F and Cl contents of the products of successive phases of the 1783 eruption of Asama volcano lead to the following conclusions.

The transition of the mode of eruption from pumice fall to pyroclastic flows and then to lava flow may be intimately related to the volatile content of the magma at the time of eruption. There may have been a vertical concentration gradient of Cl, as well as H₂O in the magma column before the eruption. The upper part of the magma had high volatile contents and vesiculated in the vent. The vesiculation in a limited space would have brought about violent explosions ejecting well-vesiculated pumice. After repetition of the pumice eruptions, the volatile content of the magma decreased until vesiculation took place at a high level in the vent and the expanding magma overflowed from the crater while continuing to release gas. This could have produced the Agatsuma pyroclastic flow. At the last stage, the magma flowed out without notable vesiculation as the Oni-oshidashi lava flow. A semisolid mass, which was formed around the fringe of the vent during the pumice eruption, might plug the vent temporarily and be thrown out with a violent outburst of compressed gases. The fall of this material may have brought about the Kambara pyroclastic flow.

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浅間火山 1783 年 (天明) 活動噴出物のフッ素, 塩素含有量

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浅間山天明活動は、降下軽石の噴出に始まり、タイプの異なる 2 種類の火砕流 (吾妻および鎌原) の発生を経て、鬼押し溶岩流の流出で終わった。これらの噴出物は、同一火口から比較的短期間に生じ、いずれも安山岩質で、主成分ならびに微量金属元素成分に顕著な変化は認められていない。著者らは、この噴出様式の変化は、噴出時のマグマからのガス放出状況の相違がもたらしたものと考え、各種噴出物のフッ素、塩素を定量し、これらの成分の揮発に関する吉田の実験結果に基づいて噴出機構を考察した。軽石試料は著しい発泡組織にも関わらず、均一で高い塩素含有量を示す。これは、噴火開始時に、マグマ柱の最上部に揮発性成分が濃縮され、火道内部で発泡して激しく放出されるとともに急冷されたとして説明される。吾妻火砕流試料は、フッ素、塩素とも含有量が最小で、変動は最も大きく、流出後にも、著しい脱ガスが継続し、火砕流の流動化に寄与したことを示唆する。一方、鎌原火砕流中の本質岩塊の塩素含有量は、軽石と鬼押し溶岩の中間の値を示し、変動幅も両者よりやや大きい程度であり、脱ガスは僅かだったことを示す。これは、火道内で生じた半融岩塊が一時的に火口をふさぎ、鬼押し溶岩を生じたマグマに押し上げられるとともに、内部ガス圧の増加により爆発的に放出されて落下して砕け、古い火山堆積物を掘り起こして流れ下ったもので、火砕流の流動化に対する本質岩塊からのガスの寄与は殆どなかったと思われる。また、鬼押し溶岩も流出後のガスの放出は少なかったと見られる。これらの結果は、昭和 61 年度自然災害特別研究で、荒牧らにより地質学的に推定された噴出状況と調和している。